of 1863, was a son of the Williams president, Mark Hopkins.

AN 800-ACRE tract of land two miles east of Chapel Hill belonging to the University of North Carolina will be made headquarters of the southeastern states in experimentation of control of soil erosion. Experiments will consist chiefly in growing trees and shrubs for highway bank protection, game conservation and gully control. A 50-foot plot has been prepared for setting out plants to be brought from the government's station at Statesville. E. L. Evinger, horticulturist, graduate of Washington University in St. Louis, is in command of the station; L. S. Haughton, formerly with the Department of Agriculture, will be plant propagater; O. L. Veerhoff, a graduate of the Johns Hopkins University, will make experimental studies in seed germination. The personnel at the station will also include natural scientists who will function as "field men," to collect plants from all over the southeast. Operations on the farm will be steadily expanded. Engineers will be sent from the soil conservation service at High Point to make a topographic survey and a soil survey of the farm. Also, an irrigation system, to cover five acres at first, will be installed. The farm will be financed by the Department of Agriculture but labor will be supplied by the North Carolina division of the Works Progress Administration, a joint enterprise of the government and the university. The project will serve as a laboratory for scientific study and eventually will become an arboretum, containing millions of trees and shrubs.

DISCUSSION

MAGNITUDE AND ENERGY OF EARTHQUAKES

LISTS and catalogues of earthquakes are frequently used for both popular and scientific purposes. Occasionally such lists are compiled without suitable discrimination, including all the shocks, small and large, which may happen to come to notice. Under such circumstances the number of earthquakes listed for any given region is likely to be a better index of the density of population than of the seismicity; for minor shocks are very frequent in all seismic regions, and even in many districts not commonly thought of as seismically active. Similar undiscriminating use of instrumental data gives undue weight to minor shocks occurring near seismological stations.

Some means evidently is required for selecting and listing the larger shocks. The logical procedure is to number shocks on a definite scale, and for general purposes to list only those of higher scale number. Several arbitrary scales are in regular use; these rate shocks in terms of intensity, which properly refers only to the degree of manifestation at a particular point. For example, intensity IV may be defined as that degree of shaking at which windows and dishes rattle, etc. Such a scale does not directly give much information about the earthquake as a whole; given effects may be due to a comparatively small shock originating near by or to a large shock at considerable distance.

When the circumstances of a shock are completely known, a rough rating is supplied by the maximum intensity manifested. However, this maximum varies with the physical conditions of the shock—depth of focus, geological structures, nature of ground, etc.—and the observations will be much affected by accidental circumstances such as the number and character of structures in the shaken area. Moreover, a large majority of strong shocks are submarine or occur in unpopulated areas, so that any reliable listing of strong shocks must depend on seismographic records.

It would be desirable to rate earthquakes in terms of the energy actually liberated in each shock; but at present the determination of such energies from seismograms is subject to large uncertainties. Accordingly, a partly arbitrary magnitude scale has been set up,[1] originally for use with local shocks of the Southern California region. The magnitude of a shock is defined as the logarithm of the amplitude written by a standard seismograph distant 100 km. from the epicenter. Thus a shock of magnitude 7 writes amplitudes 10 times as large as those for magnitude 6, 100 times those for magnitude 5, etc.; the corresponding energy ratios should be 100 and 10,000. The arbitrary zero of the scale has been chosen to coincide with the smallest recorded shocks. The smallest shocks reported felt are of magnitude 1.5, the smallest causing any damage are about 4.5, and major earthquakes exceed magnitude 7, but in most cases the intensity is distributed so irregularly that it can not be used to determine the magnitude.

This scale has now[2] been extended, with some additional uncertainty, to apply to large shocks in all parts of the world, the data being the earth motions recorded at a considerable number of stations. The largest shocks, beginning with 1904, have been investigated in this way. The selection is not difficult, as the greatest shocks produce surface waves with amplitudes of a millimeter or more over nearly the whole earth. The

[1] C. F. Richter, *Bull. Seism. Soc. Amer.*, 25: 1, 1935.

[2] B. Gutenberg and C. F. Richter, *Gerlands Beiträge zur Geophysik.* In press.

period of this large motion is about 20 seconds, so that it is not perceptible.

The resulting list includes 49 shocks with assigned magnitudes over 7½. Four of these are of magnitude near 8½; all the evidence indicates that these are really exceptionally large. The dates and places are: January 31, 1906, Ecuador and Colombia; January 3, 1911, Turkestan; December 16, 1920, Kansu (China); November 11, 1922, Atacama (Chile). Six others are of magnitude about 8¼. April 18, 1906, San Francisco; August 17, 1906, Valparaiso (Chile); June 26, 1917, Tonga region; February 3, 1923, off Kamchatka; March 2, 1933, off Japan; January 15, 1934, India. Notwithstanding its apparent high intensity, the earthquake destructive at Tokio on September 1, 1923, was somewhat smaller than these. The remaining shocks of the list range from about 7¾ to 8. The most recent shock listed is the Quetta (Baluchistan) earthquake of May 30, 1935 (about 7¾).

A number of well-known shocks are not included—such as the disastrous Messina earthquake of 1908 (magnitude about 7). The California earthquake of 1906 is the only listed shock occurring in the United States. (Of course, other large shocks have occurred in this country prior to 1904.) It may be of interest to give here the magnitudes of a few of the larger shocks of recent years in the continental United States.

Montana	June 28, 1925	6¾
Santa Barbara, Calif	June 29, 1925	6¼
Texas	Aug. 16, 1931	6½
Nevada	Dec. 20, 1932	7½
Long Beach, Calif.	Mar. 10, 1933	6¼
Utah	Mar. 12, 1934	6¾
Helena, Montana	Oct. 18, 1935	6½ ±
Helena, Montana	Oct. 31, 1935	6½ ±
Southeastern Canada	Nov. 1, 1935	7 ±

This list is in no sense complete. The last three values are tentative only. Special attention is directed to the magnitudes of the Santa Barbara and Long Beach earthquakes, as the notion still persists that these shocks, especially the latter, were great shocks of the type of the San Francisco earthquake. In point of fact the energy released in that case was probably of the order of 10,000 times that of the Long Beach earthquake. The spectacular damage and considerable loss of life in the smaller shock are chiefly to be attributed to the failure of weak structures on unstable ground.

The total of 49 great shocks in 32 years should not be taken too hastily as a measure of the seismicity of the globe. The magnitudes are calculated from the amplitudes of surface waves; this procedure applies only to shocks at normal depth. Many shocks occur at abnormally great depths; these give rise to very small surface waves or none at all, although in some cases their energy may possibly equal that of the greatest normal shocks.

Very divergent statements as to the frequency of earthquakes, for the whole earth or for particular regions, will be found in the literature. A magnitude scale or its equivalent is a necessary preliminary to reliable statistics of this character. As a preliminary sample of the sort of conclusions to be expected from investigations now under way, we offer the following results.

The occurrence of ten shocks of magnitudes 8¼ to 8½ in 32 years is a somewhat questionable index of the frequency of very large shocks, as we can not be certain that the period 1904–1935 is sufficiently long to represent the normal conditions. For the shocks of magnitude approximately 8 we find an average of roughly one a year. To arrive at estimates for the smaller magnitudes, the reports for 1926 have been examined with some care. In that year there were no shocks of magnitude 8 or over, but there was one shock of magnitude about 7½, and seven others of magnitude 7 or slightly higher. About 350 shocks were instrumentally registered over at least half the surface of the earth; this corresponds roughly to a magnitude of 6 and over. For smaller magnitudes no exact figures can be given for the entire earth, as there are large areas in which small shocks might occur without being registered at the nearest stations. The fact that about 5,000 shocks were included in the International Summary (Oxford) for 1926, which digests all available data from the stations of the world, indicates that shocks of small magnitude are very frequent. This is borne out by the results obtained at Pasadena. During 1934 a total of 213 shocks of magnitude 3 and over originated in a selected area including Southern California and a small part of adjacent Mexico. Of these 114 were of magnitude 3, 63 of magnitude 3.5, while the highest magnitudes were 5.5 and 6, represented by only one shock each. (Magnitudes are assigned in routine to half a unit.) If these ratios are generally applicable, there must be between 10,000 and 100,000 shocks of magnitude 3 annually over the whole earth. Such shocks are usually reported felt generally near the epicenter. Statistics of this kind would not include the thousands of very small aftershocks which follow each major earthquake.

As pointed out above, the relation between the assigned magnitudes and the shock energies is not known with precision. Several methods have been used to estimate the total energy liberated in the largest shocks; the results agree reasonably well, the most probable value at present appearing to be 10^{25} ergs (for shocks of magnitude about 8½). The corresponding value for the very smallest shocks registered is about 10^8 ergs. This latter energy is of course very small; but shocks of this magnitude are registered only at very short distances, and then only by the most sensitive instruments, on whose records they are barely perceptible above the usual ground unrest. Calculation using the physical constants of the instruments indicates that this should be the case for shocks in which an energy of 10^8 ergs is liberated in a very small time. Since the ratio of the largest to the smallest shocks is determined from the observations, it follows that the estimated energy for neither group can be seriously in error (probably by not more than a factor 10). This tends to remove doubts, such as have frequently been expressed, as to whether energies so large as 10^{25} ergs actually are liberated in earthquakes.

In the first paper on the magnitude scale (*loc. cit.*) it was pointed out that the seismic energy liberated in the California region during a given period is almost wholly accounted for by the larger shocks; smaller shocks are not sufficiently frequent to contribute more than a small fraction of this energy. A similar result is indicated, with slightly less definiteness, for the large shocks of the world. During the last 32 years the listed shocks of magnitude approximately 8 or over represent an estimated energy of about 10^{26} ergs, or an average of 3×10^{24} ergs annually; while in 1926, during which year none of these larger shocks took place, the total liberated energy was of the order of 2×10^{23} ergs. Very small shocks do not need to be considered; 100,000 shocks of magnitude 3 would give only 10^{19} ergs. Such evidence strongly indicates that the smaller shocks do not appreciably mitigate the strains which are released in the larger earthquakes, but must be regarded as minor incidents in and symptoms of the accumulation of such strains.

B. GUTENBERG

BALCH GRADUATE SCHOOL OF THE
GEOLOGICAL SCIENCES,
CALIFORNIA INSTITUTE OF TECHNOLOGY,
PASADENA, CALIF.
Contribution No. 187

C. F. RICHTER

CARNEGIE INSTITUTION OF WASHINGTON,
SEISMOLOGICAL RESEARCH, PASADENA, CALIF.

THE DEATH OF HUNDREDS OF CEDAR-WAXWINGS[1]

THE cedar-waxwings, *Bombycilla cedrorum* (*Ampelis cedrorum*), are chiefly distinguished by the bright red wax-like appendages on the secondary coverts of the wing feathers, although they have many other remarkable characteristics.

[1] Presented at the meeting of the Pacific Coast Division of the American Association for the Advancement of Science, June 27, 1935.

These birds feed on insects and small wild berries, scarcely ever touching cultivated fruits.

There is no noisy warning of the coming or going of a flock of "cedar-waxwings." They are very sociable and fly in flocks of very close formation while in search of food. A group of two to five hundred or more keep so closely in contact with each other that they act as if of one mind. Sometimes apparently bent upon going in a definite direction, they suddenly turn about and settle en masse on some tree or bushes, quite noiselessly, having either scented or seen the food as they flew over.

A visitation of a flock of "waxwings" to an apple orchard is welcomed, because it means less worms and better apples the next year. It is very unfortunate to have a flock of these beautiful useful birds destroyed.

On March 19, 1935, a cold morning after the rains, a rather large number of these birds entered Los Angeles, settled on some ornamental Canary Island date palms (*Phoenix canariensis*) and began feeding on the water-soaked dates. The delicious odor and the sweetness of the fruit proved to be a fatal lure; for shortly after they had eaten of the dates the birds began to fall all about dead or dying in one to ten minutes of asphyxia or paralysis-like symptoms. Some recovered after a longer time and flew away. It was noticed that most of the fatalities occurred about one tree. Some of the birds were obtained the next day and autopsies were performed.

In each bird the post-mortem conditions were the same. At the base of the skull of the posterior portion of the cranium, between the supra-occipital and the atlas, in the region of the foramen magnum, there was a large accumulation of blood. The lungs and right side of the heart were full of blood, and the liver and kidneys congested. The blood in general was rather light red in color.

Pieces of the outside of the dates, meat and hull were found in the digestive tract. Pieces as large as half a date were found in the crop, showing the birds had fed very greedily. The birds were in good condition, plump and fat. No parasites were discovered, and no evidence of infection with microorganisms was found, also no indications of metallic poisoning. No pathology was noted.

The dates were bruised and water-soaked. The outer covering remained mostly intact, while the inside consisted of a watery mushy pulp.

The syndrome, or picture, obtained from the symptoms and post-mortem findings gave evidence of hydrocyanic poisoning.

Conclusions were that the prolonged cold rains and bruising of the fruit by the whipping of the winds, had destroyed the protoplasmic structure of the date